PATENT SPECIFICATION

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519,577

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Complete Specification Accepted: April 1, 1940.

COMPLETE SPECIFICATION

Improvements in or relating to a Three-dimensional Structure Made by Folding Sheet Material, for Example Paper

I, PAUL RINKEL, a German Citizen, of 7—8, Joachimsthaler Strasse, Berlin-Charlottenburg, Germany, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

The invention relates to a three-dimensional structure made by folding sheet material, for example paper. Boxes or containers or other articles for packing may be made in this manner and may also be used as ornamental articles or as structural elements for building up other objects.

It is known to make boxes, cartons or like bodies by scoring lines in a plane sheet of material such as paper and then making folds along these lines. Bodies having curved adjoining panels have already been formed in this way from plane sheets, by using non-rectilinear folding lines. Flaps consisting of extensions to the sheets have served for the production of bases and lids for the bodies. By suitable arrangement of the folding lines, not only cubes, prisms, cylinders, pyramids and cones are then obtained, but also bodies the outer surfaces of which possess arches which adjoin one another in curved edges, or also bodies which converge more or less conically with plane surfaces adjoining at different angles.

The present invention provides a three-dimensional substantially rigid and non-deformable structure adapted to serve as a container, ornament, lampshade, building element or the like and made by folding sheet material such as paper, around the major axis of the structure, and having at a plurality of positions along an axis, similar cross-sectional outlines possessing rotational symmetry, said structure being developable into a plane surface and having fold edges defining panels in the wall of the structure between said cross-sectional outlines, in which the fold edges are so curved or so extend obliquely relatively to said major axis that in a plurality of sections taken on planes in which said major axis lies, at the intersection of such planes with the wall of the structure between said similar outlines panels alternate with fold edges or corners.

The word "similar" used herein in connection with the cross-sectional outlines has its geometrical meaning indicating the same shape but not necessarily the same size, and in addition is intended also to cover the case of a mirror image.

There may be only two positions along an axis of rotational symmetry the structure possessing similar cross-sectional outline, for example at the base and the top of the structure. Alternatively, the structure may comprise a longitudinal series of similar sections or zones, each section comprised by a portion between adjacent positions of similar cross-sectional outlines. Further, the similar cross-sectional outlines at adjacent positions may be relatively angularly displaced about their common axis, for example the outlines may be squares with the diagonals at one position at 45° to the diagonals of the square at the adjacent position.

If the panels of the structures have widths which vary longitudinally but periodically so that the same widths recur, then a plurality of similar structures can be packed closely together, interfitting so that there are no appreciable unoccupied spaces between them.

The structures of the present invention have greater rigidity than structures of similar material but of simple shapes such as cubes and prisms. The rigidity of the structures is considerably improved by providing curved panels or undulating walls which are obtained by curved or bent longitudinally extending fold edges.

In one embodiment of the invention, closely spaced converging fold lines are scored at intervals between panels in the development sheet from which a structure is folded, and the parts between such closely spaced fold lines become mutually superposed on folding and form substantially transverse ribs in the structure.

The bodies or structures which are folded from plane sheets may also be

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wrapped with clinging sheet material. This is particularly simple to achieve in the case of those bodies which have no re-entrant corners in any cross-section.

A structure of the present invention may consist of a skeleton or framework of rods or ribs corresponding to the fold edges of a folded sheet structure, the framework being wrapped by a sheet of flexible material stretched around the framework and thus assuming the envelope configuration thereof. Lamp-shades may be made in this way.

According to one embodiment of the invention the fold edges of the structure may be arranged to define V-shaped longitudinally substantially helically extending panels so that the structure as a whole has the appearance of a longitudinally, substantially helically recessed column. Such a structure is resilient to torque about its longitudinal axis and consequently can be employed as a fluid pressure indicating appliance, for example, as variations in the internal pressure of the structure cause longitudinal elongation or contraction and thus relative twisting of the ends of the structure, such twisting may be utilised to move a pointer over a graduated scale and thus indicate the pressure variation.

The structures are produced from developments of sheet material on which are scored or marked lines corresponding to the folds.

The invention is illustrated in the accompanying drawings, which illustrate diagrammatically and by way of example, a number of embodiments thereof, and in which:—

Figs. 1 to 10 show quite generally the basic construction of the folded bodies, with both straight and curved fold edges and also with inward and outward folding;

Fig. 11 shows a polyhedral hollow body in perspective;

Fig. 12 shows the corresponding blank;

Figs. 13, 14, 15 and 16 show respectively the plan, cross-section, perspective and plane development of a body having edges projecting alternately inwards and outwards and twisted relatively to one another;

Fig. 17 shows a body produced by placing two bodies of the type illustrated in Fig. 11 on one another over a hexagonal prism;

Figs. 18 and 19 show a perspective and the plane development of a body built up of two octahedra;

Figs. 20, 21 and 22 show a hollow body composed of a superposed series of portions each resembling a base-to-base pair of four-sided pyramids.

Figs. 23 and 24 show a hollow body composed of a superposed series of double-convex and double-concave walled portions interconnected by narrow rectangular ends;

Figs. 25 and 26 show in perspective, hollow bodies with curved fold edges;

Figs. 27 to 30 are illustrations of a hollow body built up on a square as a base, wherein panels doubled flat on one another form oblique ribs, which are shown in the blank as simple, oblique lines marked out between straight folding edges, Figs. 28 and 29 being merely transverse sections at different points through the body shown in Fig. 27 for the purpose of showing the particular shape of the walls of the structure;

Fig. 31 illustrates the use of such a body as a packing distance piece;

Figs. 32 and 33 show the perspective and the plane development of a hollow body built up of a plurality of pyramidal portions with radial partitions or ribs therebetween;

Figs. 34 and 35 show a hollow body with double concave and double convex walls between a square as a base and narrow rectangular ridge.

Fig. 36 shows in perspective, a helically fluted body having concavely curved panels and oblique fold edges;

Figs. 37 to 39 illustrate a body with regular sinuous fold edges, Figs. 37 and 38 showing an auxiliary folding line for flat folding of the body for flat packing and Fig. 39 a plurality of bodies packed together without superfluous hollow spaces between them; and

Figs. 40 and 41 show examples of the wrapping of clinging materials around such hollow bodies, Fig. 41 showing a framework body in which the fold edges are replaced by the frame bars.

In all the figures, the solid lines between the boundary lines denote outwardly directed folding edges, while the broken lines represent folding edges to be folded inwards. Edges 1 and 4 (Fig. 1) are folded inwards, 2, 3, 5, 6 and 6^1 outwards. Fig. 2 shows a plan-view and Fig. 3 an elevation of the folded body itself.

The mathematical relations will be explained with reference to Fig. 4. Let the angle enclosing the folding edge 9 with the strip edge 10 or 11^1 be equal to α. Then

$$\tan \beta = \frac{a}{c}$$

$$\tan \alpha = \frac{b}{c}$$

therefore

$$\frac{\tan \beta}{\tan \alpha} = \frac{ac}{cb} = \frac{a}{b}$$

as

$$\tan \gamma = \frac{a}{b}$$

then

$$\frac{\tan \beta}{\tan \alpha} = \tan \gamma = z$$

Since when travelling round the zone γ becomes alternately positive and negative, $\tan \gamma$ and thus also the relationship $\frac{\tan \beta}{\tan \alpha}$ becomes alternately equal to $+z$ and $-z$.

The following rules are thus obtained: where angles β follow one another with the same sign, thus where the edges either project only inwards or outwards, the angles α receive alternating signs. In these cases backwardly and forwardly inclined edges, with respect to an axis normal to the base, follow one another (edges 2 and 3). Where the signs of consecutive angles β change, consecutive angles α receive the same sign. The edges which follow one another are then inclined in the same direction with respect to an axis normal to the base (edges 3, 4, 5 and edges 6, 1, 2). The necessary position of the folding edges can thus previously be determined in the blank, and at the same time it can be determined which edges must be pinched or folded inwardly and which must be pinched or folded outwardly.

These rules apply to any folded bodies, either complete bodies or portions thereof or similar bases or cross-sectional outlines. Figs. 5 to 8 illustrate the construction of a portion of a complete body. The curved edges 24 and 25 correspond to the fold lines 1, 13 and 2, 14. An arched panel between the curved edges 24 and 28 corresponds to the panels 7 and 19, and the concave arched panel between the curved edges 24 and 25 corresponds to the panels above and below the re-entrant edge 21. The panel 19 is similar to the panel 7. The edges 1 to 6 are found again in the edges 13, 14, 15 and so on. The folding edges 20 and 23 (and so on) will alternately project outwards and inwards. The transition to the curved edges 24 to 28 in Figs. 7 and 8 is clearly visible.

In the case of three portions or zones (Figs. 9 and 10) in which the uppermost zone corresponds to the strip 7, and the lower zone 30 with straight folding edges running at right angles to the base (angle $\gamma = 0$) is a prism, the connecting middle strip 29 is flatter than strip 7, but inclined in the same direction.

From these basic forms a large number of the most diverse structures is produced. In the blank shown in Fig. 12 are found the inwardly directed edges 31, the outwardly directed edges 32, the base surfaces 33 with the adhesive strips shown by cross shading. In Fig. 11 a middle section which clearly shows the inwardly directed parts is shaded. On alternating outwardly directed edges 35 with inwardly directed edges 36 and scored lines lying at an angle, in accordance with Fig. 16, the body Fig. 15 with the star-shaped cross section of Fig. 14 in the middle is obtained.

If two bodies of the type shown in Fig. 11 are placed one on the other, over a hexagonal prism, a hollow body of the type shown in Fig. 17 is obtained. The first two zones are twisted at an angle of 60° to one another. With the exception of the outwardly directed edges 37, the surface parts of the upper and lower zones meeting one another merge into one another without an edge, as the inclinations are equal. In the section of contact with the bottom prismatic zone, all six edges are shown, of which two are inwardly directed (38) and two outwardly directed (39)

The superposing on one another of bodies having horizontal partitions between panels folded on one another is naturally not restricted to those bodies in which the folding lines are at right angles to the base surface. In the embodiment shown in Fig. 18 produced from the blank shown in Fig. 19, two octahedra are placed on one another so that the zones forming the body are split up into triangular fields in the blank. Between these zones lies the intermediate partition portion, folded flat, bounded by the subsequently inwardly directed folding lines (shown in broken lines), between which are provided the obliquely directed folding lines which again have an inclination to the base equal to half the outer angle of the polygon.

Fig. 20, with the development network shown in Fig. 22, shows hollow bodies composed of a number of sections or zones each comprising a base-to-base pair of four-sided pyramids. Inwardly directed edges 45 define the triangular cross-section outlines between the zones. Such a hollow body is to be used, for example, as packing for chocolate. If the content be formed as a rod of corresponding shape, it is extremely simple to break the same apart in the planes of the inwardly directed edges 45. Fig. 21 shows how the packed contents can be divided into equal pieces 46. The portion located in the parts of the packing broken away from one another, for example the pieces of chocolate, cannot fall out of the packing.

A modification is illustrated in Figs. 23 and 24, wherein the hollow body consists of a number of identical portions or zones 47 with very narrow rectangles as end surfaces. The rectangles between portions are defined by sharply inwardly directed folding edges 48, so that the body may easily be broken up. The narrowed portions of the cross-section in themselves effect a pre-division of the contents.

The hollow bodies shown by Figs 25, 26 are formed with curved folding edges. The folding edges 49 and 50 are directed alternately outwardly and inwardly. The hollow body shown in Fig. 26 consists of two halves one of which is the inversion of the other, the upper half being identical with the upper half of the body shown in Fig. 25. Each curved edge has one concave surface on one side and one convex surface on the other side.

In the body shown in Figs. 27 to 30, the inwardly directed edges are so placed that the basic squares are, as it were, connected by ribs. On both sides of the edges 51 and 52 the triangular surfaces lie flat on one another. The middle section (Fig. 29) shows a cross; Fig. 28 shows the extension of the cross-sectional polygon by the ribs—all in the same clockwise direction.

Fig. 31 shows the application of the invention to a package in which a bar 53 is held by the packing 55 at a certain distance from the surrounding hollow body 54. To this end the folding body, otherwise corresponding in repetition to Fig. 27, is furnished with apertures 56, lying in the axial direction.

Figs. 32 and 33 show a conical body with intermediate zones folded together to form horizontal partitions. This example corresponds fundamentally to Figs. 18 and 19, and is merely intended to act as an example of the manifold possibilities of the formation of bodies by applying the basic idea of the present invention

In Figs. 34 and 35 is shown the development of a body with curved folding edges, a square base and a narrow rectangle as the other end surface or ridge. The auxiliary fold lines 57 permit the blank to be folded flat for storing.

Fig. 36 shows an embodiment in which outwardly directed edges 59 correspond to the edges 35 in Fig. 15. Inwardly directed edges, however, are not provided. On the other hand, concave curved panels are automatically formed between two adjoining outwardly directed folding edges 59 owing to the tensions produced in the material on erection.

The structure shown in Figs. 37 to 39, is quasi-prismatic. The ascending folding edges are undulating lines, whereby undulating curved outer surfaces are formed, which give the body extraordinary stiffness. The inscribed prism affords the possibility, when used for packing material, of mechanically protecting the contents by the waves of the surrounding hollow body and to hold them resiliently at a certain distance from the outer covering. This property may be advantageously utilised for insulating purposes. In addition, the bodies can be packed very favourably. In the plan-view shown in Fig. 39, the broken lines 63 represent cross-sectional lines through the section A—B of the blank (Fig. 38). They show that the cross-sections fit against one another well, so that the bodies can be packed close against one another without producing superfluous hollow spaces in addition to those absolutely necessary. The auxiliary folding lines 60, together with the edges 61, which correspond with the auxiliary folding lines 60 after the body has been fitted together, permit the body to be folded flat.

Fig. 40 shows how a body, which is made in accordance with the invention, may be wrapped with a sheet 65, and how this wrapping clings directly to the surface of the body 64 at all parts thereof. The reason is simply that the surrounding surface of the body 64 itself is developed from a plane blank. A further example of this type is shown in Fig. 41, in which the folding edges only are represented by a framework, instead of a walled body. If a wrapping, consisting for example of transparent paper or cloth 67, be used for this framework, the strip of paper or cloth folds smoothly around the edges 66, and a three-dimensional sheet structure is produced. Lamp shades may be made particularly well in this manner, the sheet passing smoothly around the edges without additional folding. The sheet is preferably previously cut to shape so as to correspond with the developed surface of the body.

All the folded bodies can be produced in simple manner by furnishing a correspondingly large sheet with lines representing the developed network of the hollow body. It is immaterial whether the lines are plotted only as a network of lines, or whether mechanical depressions or grooves are made.

The sheet from which the three-dimensional sheet structure is to be produced may also be placed around a com-

pleted body having the superficial shape of such a body, so that the shell assumes the same superficial shape. The core body may in such case be either a folding box, which is wrapped with a transparent cellulose skin, for example, or the previously suitably shaped object to be packed itself. Alternatively, it may be a frame with the bars as folding edges, as is also described in the examples given.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1). A three-dimensional substantially rigid and non-deformable structure adapted to serve as a container, ornament, lampshade, building element or the like, and made by folding sheet material such as paper, around the major axis of the structure, and having at a plurality of positions along an axis, similar cross-sectional outlines possessing rotational symmetry, said structure being developable into a plane surface and having fold edges defining panels in the wall of the structure between said cross-sectional outlines, in which the fold edges are so curved or so extend obliquely relatively to said major axis that in a plurality of sections taken on planes in which said major axis lies, at the intersection of such planes with the wall of the structure between said similar outlines panels alternate with fold edges or corners.

2). Structure as claimed in claim 1, in which panels between adjacent longitudinal fold edges possess equal average width, so that a plurality of the structures can be packed closely against one another and without appreciable waste of space.

3). Structure as claimed in claim 1, in which longitudinal fold edges have the shape of a preferably regular undulating line, so that the structure possesses undulating walls of considerably increased strength.

4). Structure as claimed in claim 1, in which closely spaced converging fold lines are scored at intervals between panels in the development sheet from which a structure is folded, and the parts between such closely spaced fold lines become mutually superposed on folding and form substantially transverse ribs in the structure.

5). Structure as claimed in claim 1, in which adjacent panels are folded to become superposed and provide oblique strengthening ribs.

6). Structure as claimed in claim 1, having a substantially conical shape, so that the longitudinal outline of the structure tapers from one of its end boundaries to the other.

7). Structure as claimed in any of the preceding claims, in which in addition to those folding edges which serve for the production of the desired shape, auxiliary folding lines, rectilinear in the development, are also provided, which enable the body to be folded flat for storing.

8). A structure as claimed in any of the foregoing claims, in which the structure is wrapped with clinging sheet material.

9). A structure as claimed in claim 8, in which the structure to be wrapped is replaced by a framework of bars, rods, wires or the like in which the bars run along the fold edges.

10). A framework and wrapping as claimed in claim 9, when used as a lamp shade.

11). A structure as claimed in claim 1, with longitudinally helically extending panels and formed from resilient material for use as a pressure sensitive torque element for pressure gauges.

12). The three-dimensional sheet structures, substantially as described with reference to the accompanying drawings.

Dated this 19th day of August, 1938.

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14—18, Holborn, London, E.C.1,
Agents for the Applicant.

Leamington Spa: Printed for His Majesty's Stationery Office, by the Courier Press.—1940.

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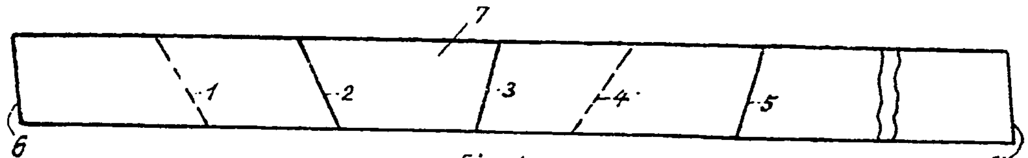


Fig. 1

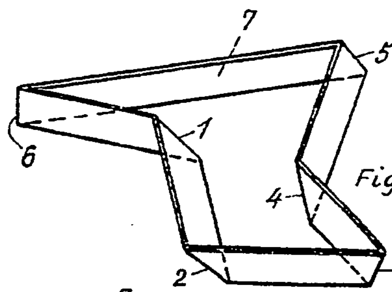


Fig. 2

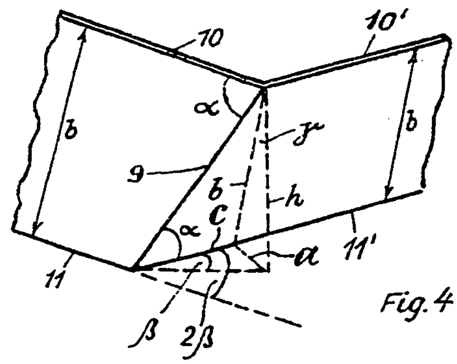


Fig. 4

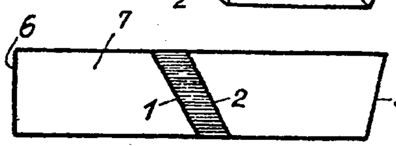


Fig. 3

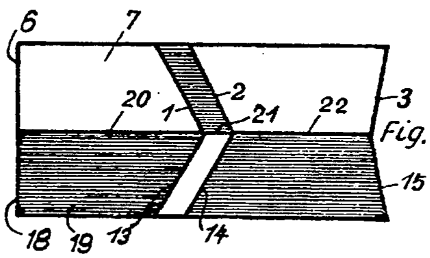
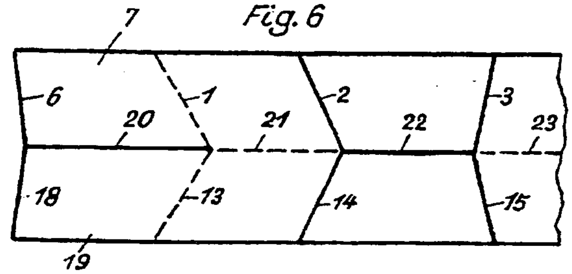


Fig. 5

Fig. 6



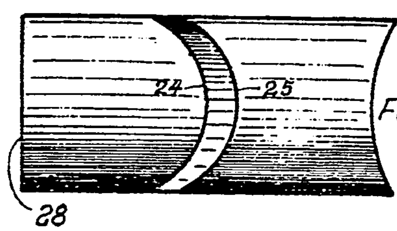


Fig. 7

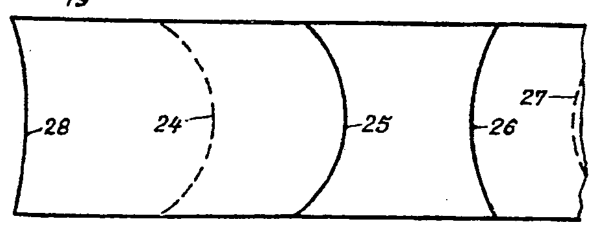


Fig. 8

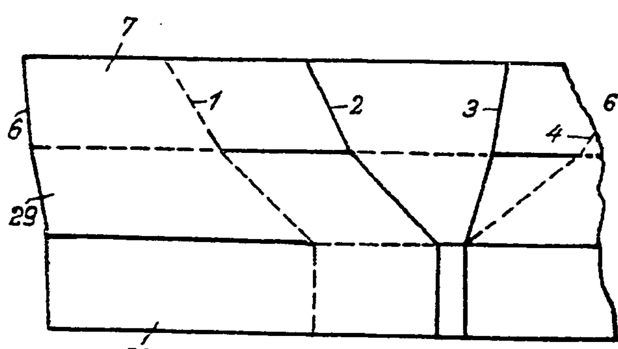


Fig. 10

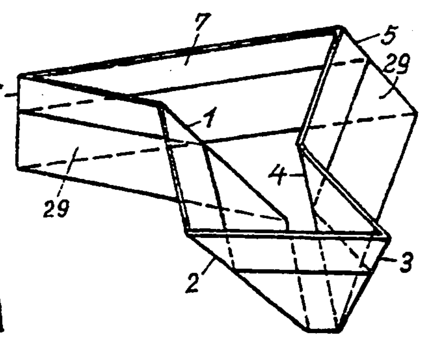
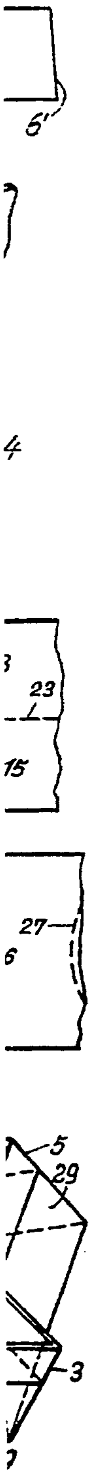


Fig. 9

SHEET 1



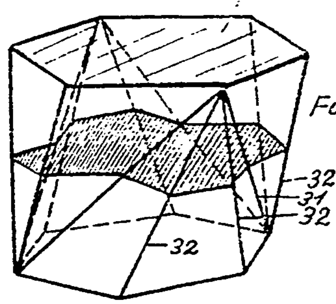


Fig. 11

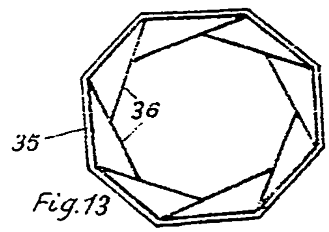


Fig. 13

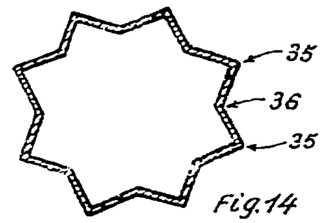


Fig. 14

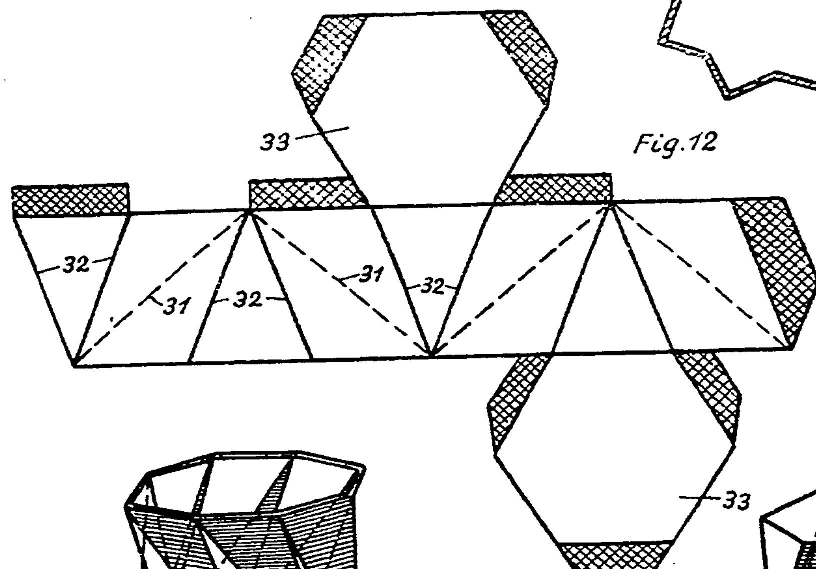


Fig. 12

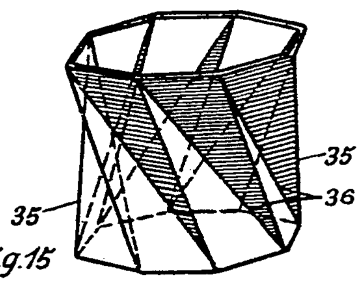


Fig. 15

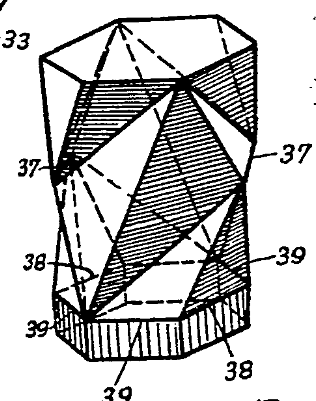


Fig. 17

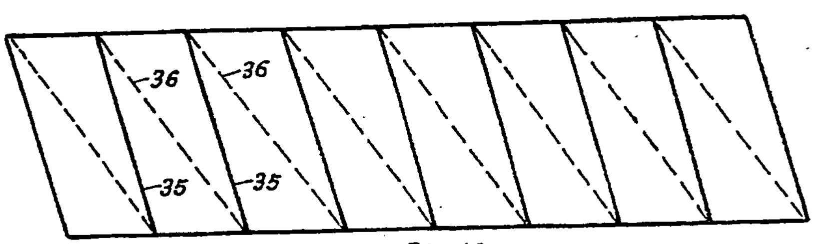


Fig. 16

Malby & Sons, Photo-Litho.

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6 SHEETS SHEET 2

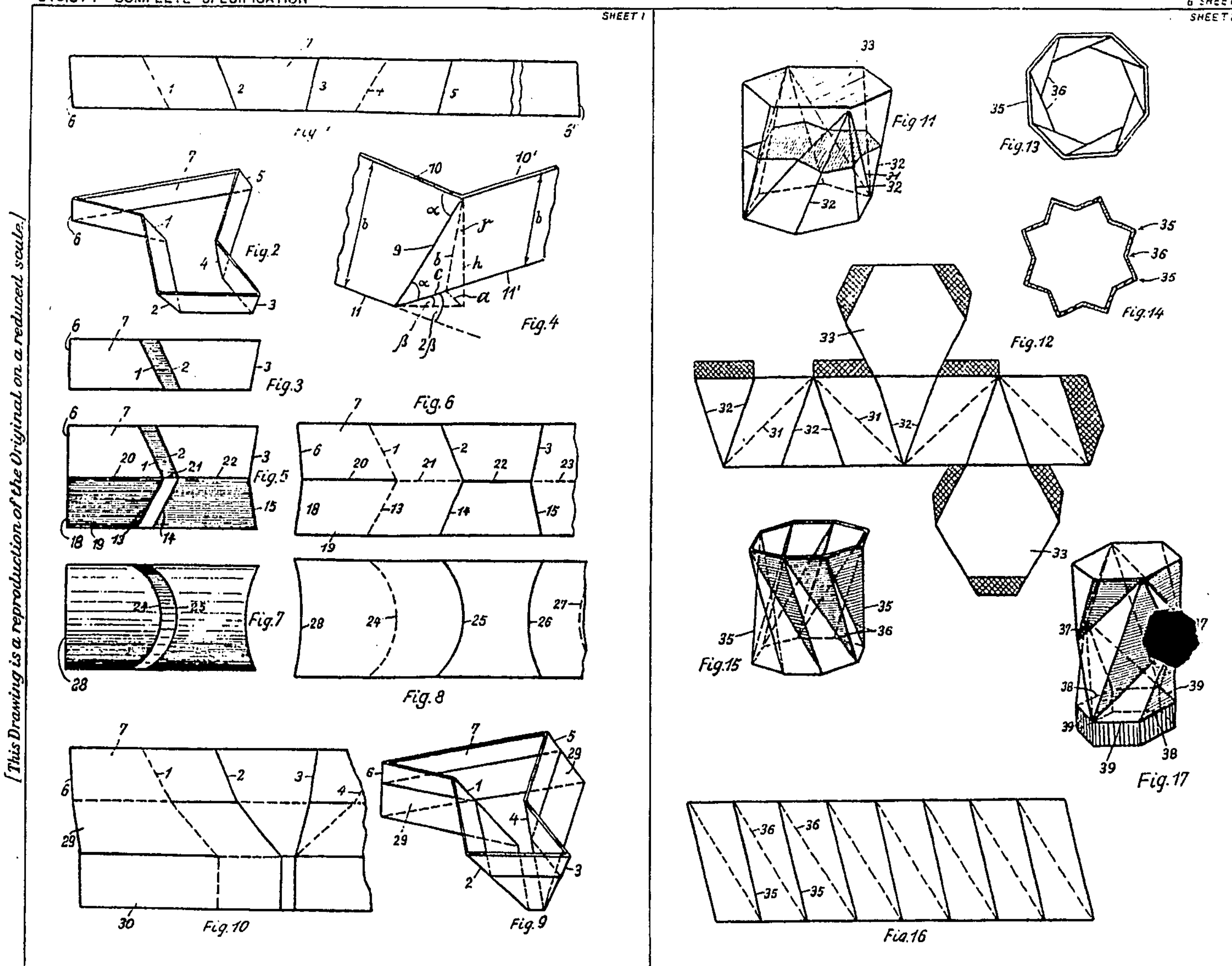

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Fig.18.

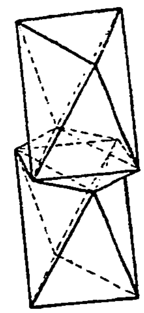
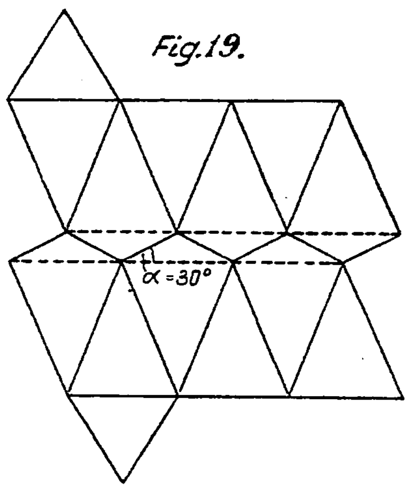


Fig.19.



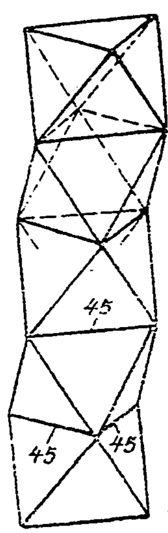


Fig.20

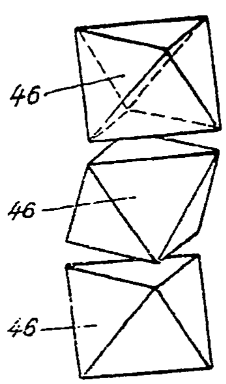
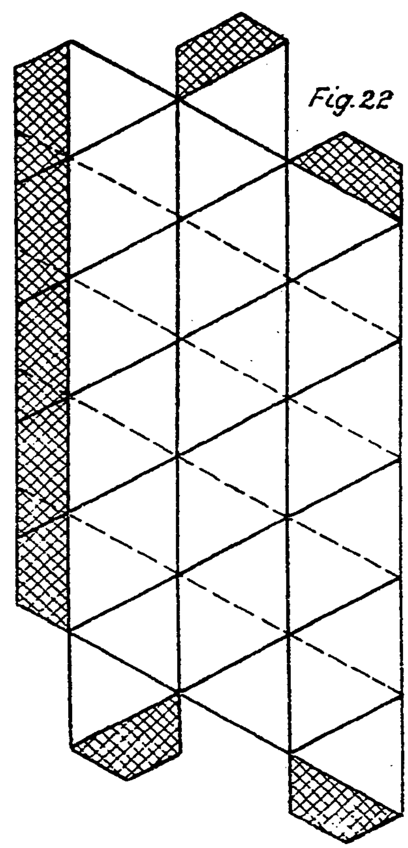


Fig.21.

Fig.22



SHEET 3

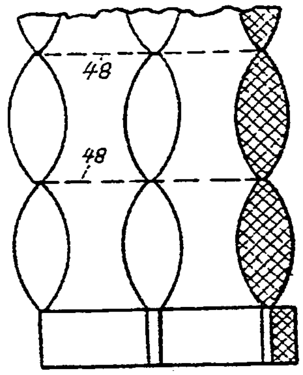


Fig. 24

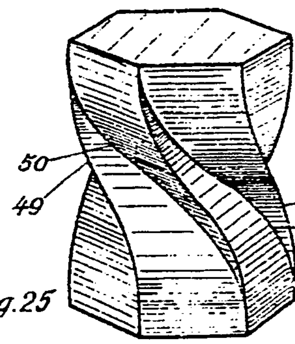


Fig. 25

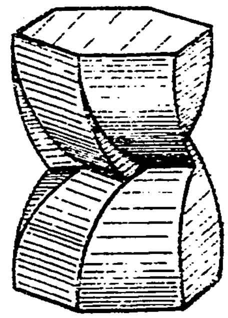


Fig. 26.

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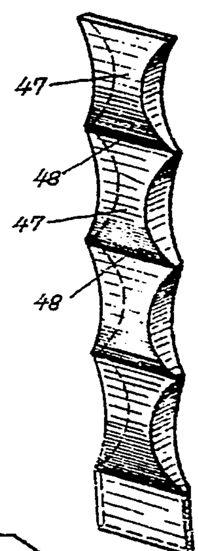


Fig 23

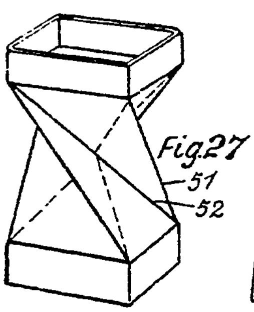


Fig. 27

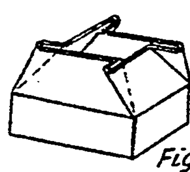


Fig. 28

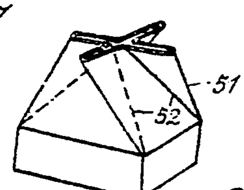


Fig. 29.

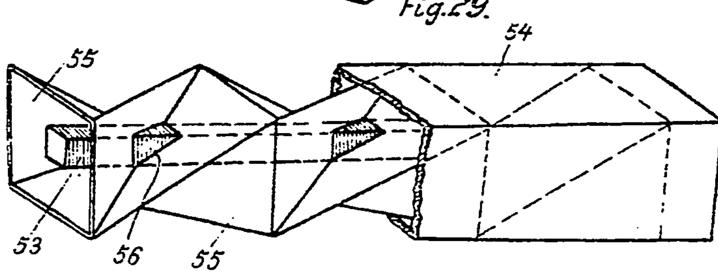
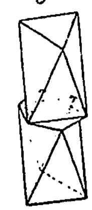


Fig. 31.

519,577 COMPLETE SPECIFICATION

6 SHEETS

SHEET 3



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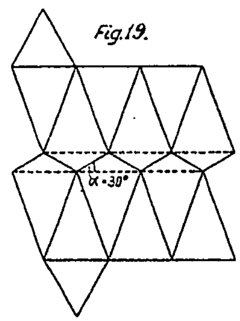

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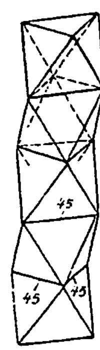
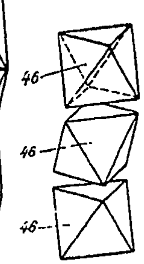


Fig.20



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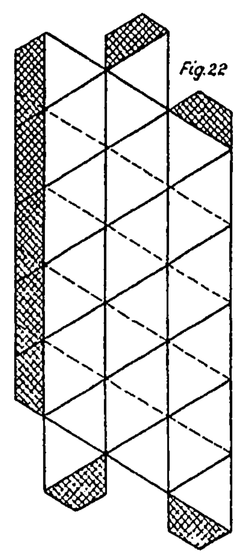


Fig.22

SHEET 4

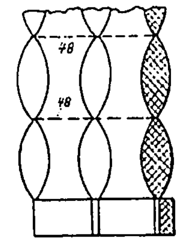


Fig.24

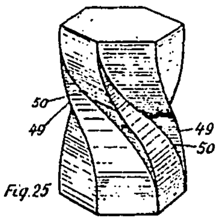
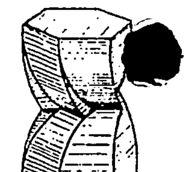


Fig.25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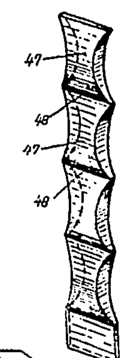


Fig 23

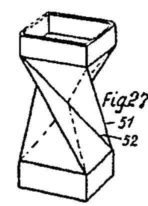
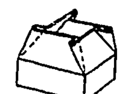


Fig.27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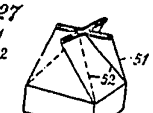

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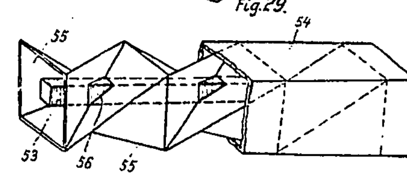

Fig.31.

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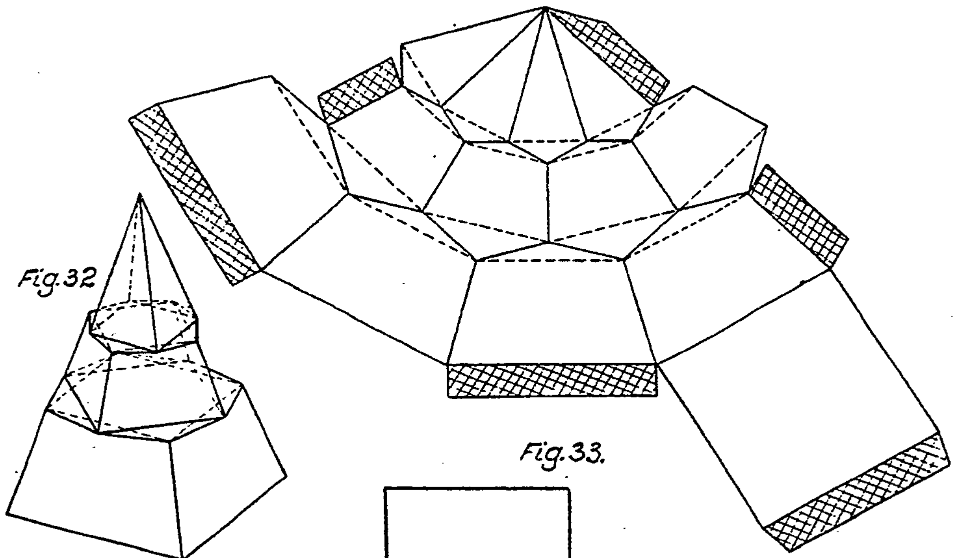


Fig.33.

Fig.32

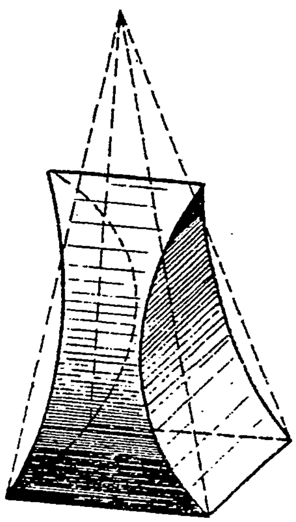
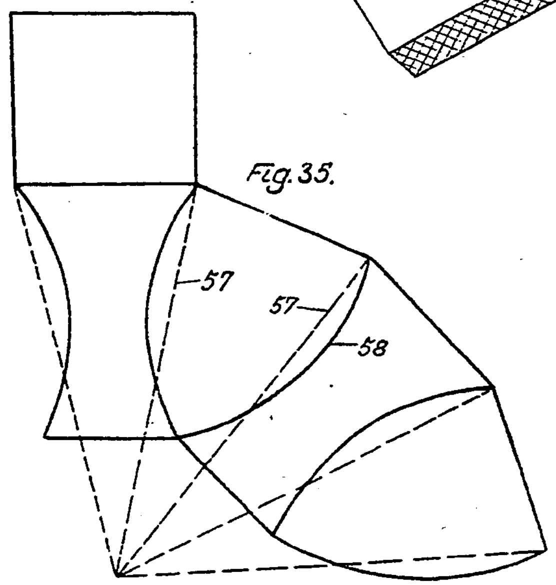


Fig.34



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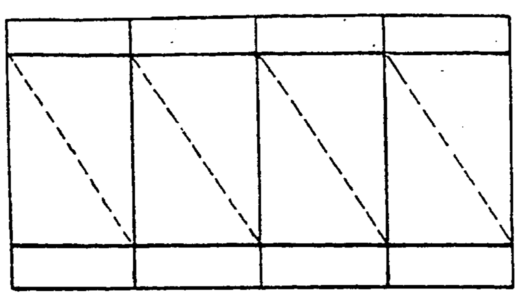

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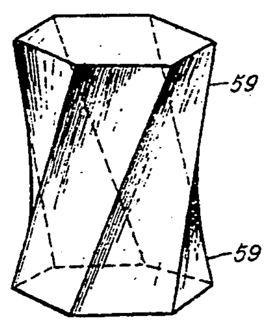

Fig.36

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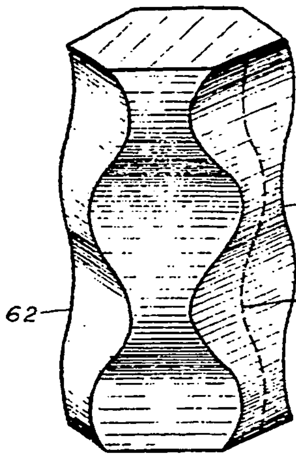


Fig.37.

Fig.39.

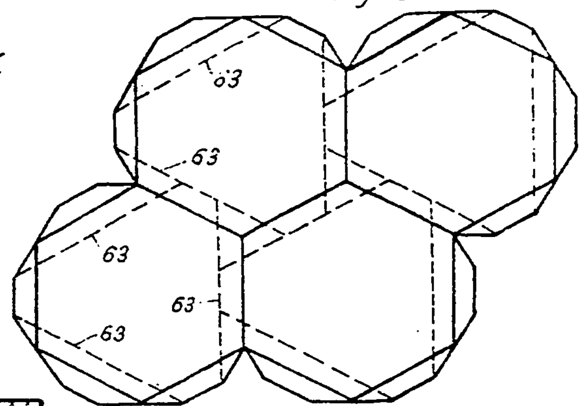
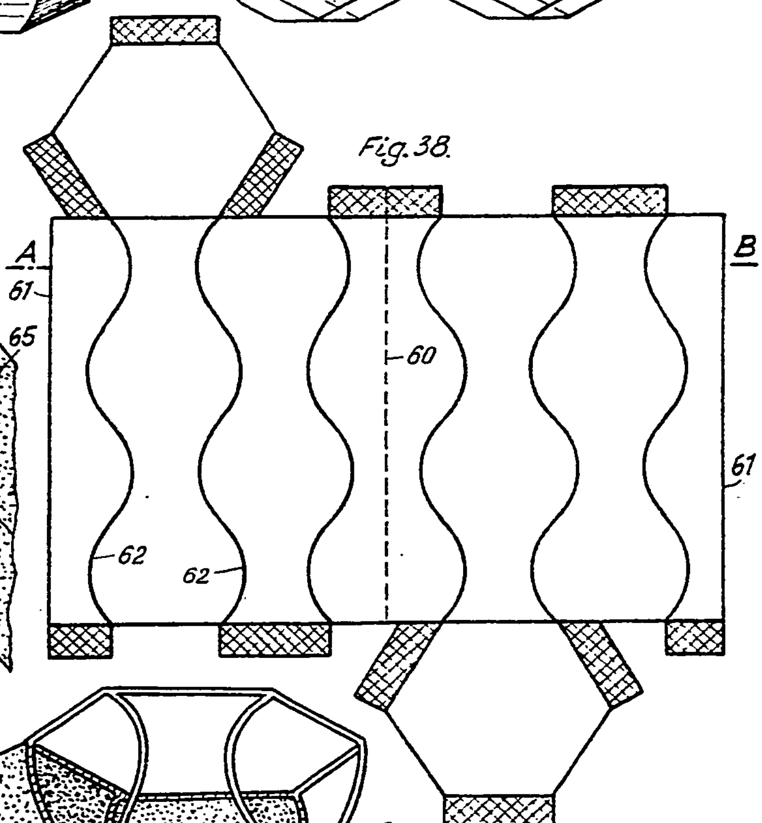


Fig.38.



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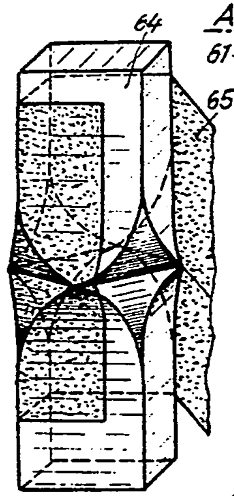


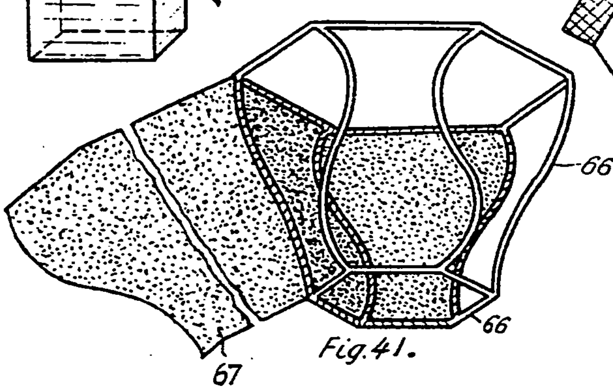


Fig.41.

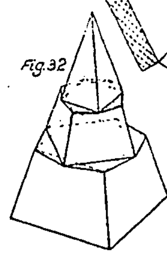
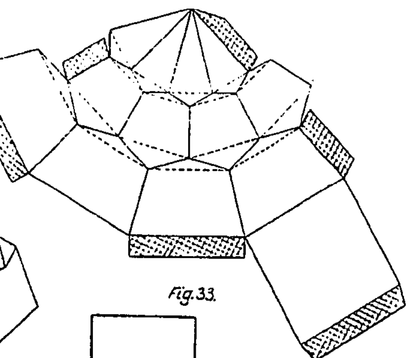


Fig.32



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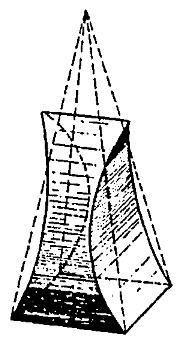
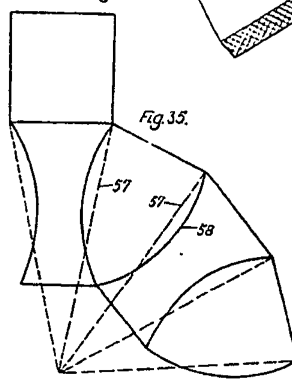


Fig.34



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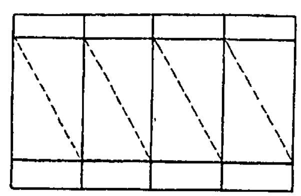

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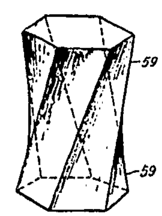
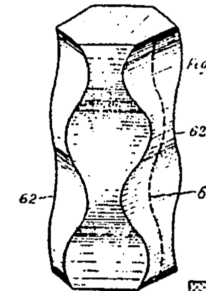


Fig.36



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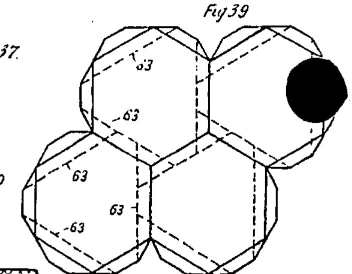

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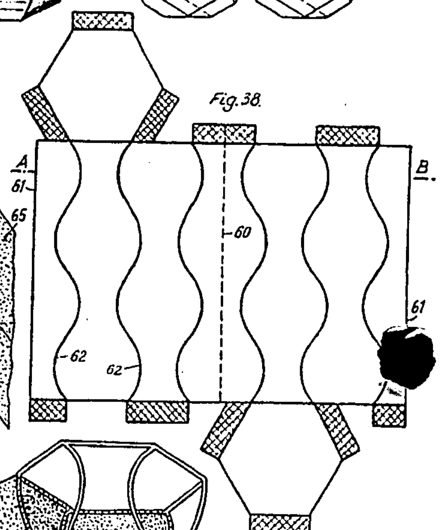

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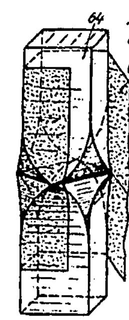

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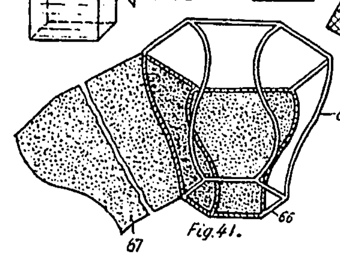

Fig.41.

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